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16. Abstract

An investigation is made of maximum performance and circadian rhythm of physiological functions in students of the Moscow Medical Institute. It is concluded that periods of high performance are determined by the circadian rhythm of physiological functions.

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PERIODS OF MAXIMUM PERFORMANCE AND CIRCADIAN RHYTHM OF PHYSIOLOGICAL FUNCTIONS

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Human performance is largely determined by the individual biological /140* rhythm of psychophysiological functions (B. S. Alyakrinskiy; Metz; Golquhoun). It is considered normal that the most intensive work activity is also timed to the period of the most intensive level of physiological processes; the curve of the work schedule must coincide roughly with the physiological curve of rhythmic fluctuations in functions or at least be close (A. A. Markosyan; Kleitman). If work is performed at hours unsuitable for the body a reduction in efficiency is observed and even development of pathological conditions. As an illustration we can use work on the night shift when the functional level of the body is very low. During this period the majority of researchers note an increased rate of mistakes and accidents, progressive fatigue, etc. (G. M. Gambashidze; M. G. Babadzhanyan and L. A. Muksinova; G. Leman, and others). People working the night shift most often suffer from diseases of the gastro-intestinal tract, cardio-vascular disorders (Pierach; Franke; Schmid).

The classical curve of performance in the daytime ("bigeminus") was de- /141 scribed by Graf in 1933. The model was supplied by people employed in physical work. Changes in the specifics of work and the increased role of mental work has directed attention to the fact that this curve is far from universal. In examining large student groups, it was found that the dynamics of indirect

*Translator's Note: Numbers in margin indicate pagination of original foreign text.

indices of performance show significant individual fluctuations in amplitude and direction of shifts (V. A. Doskin et al.).

To study causes of this phenomenon we undertook the present work, composed of two stages. In the first stage, an epidemiological study was made of individual performance characteristics of 108 students of the Medical Institute. In the second stage of the observations, data were compared with characteristics of the circadian dynamics of physiological functions of the students.

For epidemiological studies we revised and supplemented Hampp's method. In modified form it consisted of 50 questions, most of them secret, and a certified part. Questions concerned the rhythm of sleep and wakefulness, feeling and mood at various times when awake, characteristics of performance at different times of the day and the stability of the rhythm of performance.

Depending on the answers, all examinees were divided into 3 groups. In the 1st group (morning type) were placed persons who woke up early, rapidly achieved a high level of wakefulness after awakening, had a high vital tone in the first half of the day and experienced a reduction of all these indices in the evening. These people considered morning hours or the first half of the day as the optimum period for mental activity.

The evening type was observed in those in the second group who, as a rule, woke later, were sluggish in early morning hours; their functional state gradually increased in the second half of the day and their optimum performance period was in the evening or at night.

The third group consisted of persons with nondifferentiated or difficult to diagnose type performance. Here are also included persons who noted no changes in their performance level in the wakeful period.

The classical curve of performance ("bigeminus") characteristic of certain individuals was attributed to one of these groups depending on the predominance of the first or second rise.

Circadian dynamics were studied in 15 persons selected at random. Under conditions of partial social isolation every 3 hours (interval selected in accordance with the recommendations of Halberg and Panofsky), feeling, activity and mood were determined in these persons by the method we devised as well as body temperature (Kleitman method), pulse rate, muscle strength and in 2 cases diuresis (Zimnitskiy test).

The method of determining feeling, activity and mood was based on the principle of semantic differential (Osgood et al.). The subject was asked to evaluate his feeling, activity and mood on a 7-point scale between diametrically opposed signs (for example, "healthy 3-2-1-0-1-2-3 sick," etc.). Each category is characterized by 10 pairs of words reflecting various shades of feeling, activity and mood. In interpreting point charts, signs are changed to a scale of 1-2-3-4-5-6-7 with high values for positive aspects of the sign. Feeling, activity and mood are evaluated by the arithmetical mean for the 10 pairs characterizing them and the spread of values for each pair (standard deviation of arithmetical mean).

Analysis of direct interviews of students concerning the characteristics of their performance rhythm showed that among 108 subjects 55% were of the morning type, 35% the evening type and 10% had a nondifferentiated performance rhythm ("arrhythmia") or difficult to diagnose rhythm. /142

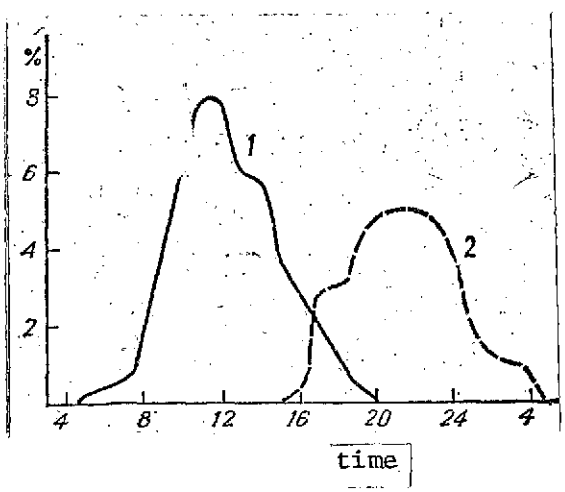

Figure 1. Distribution of maximum performance.

1 — students with morning rhythm;
2 — students with evening rhythm.

The distribution of periods of maximum performance in students with the morning and evening types is given in Fig. 1. Lowest performance in both groups is noted during the day, from 2-3 p.m. to 5-6 p.m. Only individual students reveal high performance at night.

The majority of subjects "noticed" their performance rhythm at the Institute and only several in high school. This is evidently because individual performance rhythm is revealed only with sufficiently long and concentrated activity.

Among the persons subjected to a study of the dynamics of physiological functions throughout the day, 7 were of the morning type, 5 of the evening type and 3 had nondifferentiated or difficult to diagnose rhythm.

Depending on the particular performance type, the dynamics of fluctuations in physiological functions varied significantly in the subjects. As can be seen from Fig. 2, for student I with the morning type of performance, the lowest physiological indices were noted at 1-3 a.m. By 6 a.m. a definite rise in functional level was noted which preceeded the usual awakening for this subject at 6:30 a.m. and determined a high level of wakefulness in the first half of the day. In student P with a sharply pronounced evening type of performance at 6 a.m. the functional state of the body was at the low "night" level, forced awakening at 7 a.m. was very difficult. She felt sluggish the entire first half of the day and a high level of wakefulness was reached only after 6 p.m.

Along with changes in feeling, activity and mood, the subjects experienced a change in body temperature, pulse rate and muscle strength. In subject K with the evening type of performance and, therefore, with maximum function in late evening hours, night diuresis slightly exceeded that of the daytime, despite a standard water drinking schedule and routine during the day. In subject P with the morning type of performance daytime diuresis significantly exceeded that of the night.

When functions diverged the subjects did not feel well. Student V felt bad when pulse rate and body temperature diverged in the morning.

Maximum effectiveness of directed activity is noted with the use of individual biological rhythms. Student S (athlete, track and field sports) easily /143 mastered new athletic skills, had good results in practices and competitions at hours coinciding with his optimum psychophysiological functions.

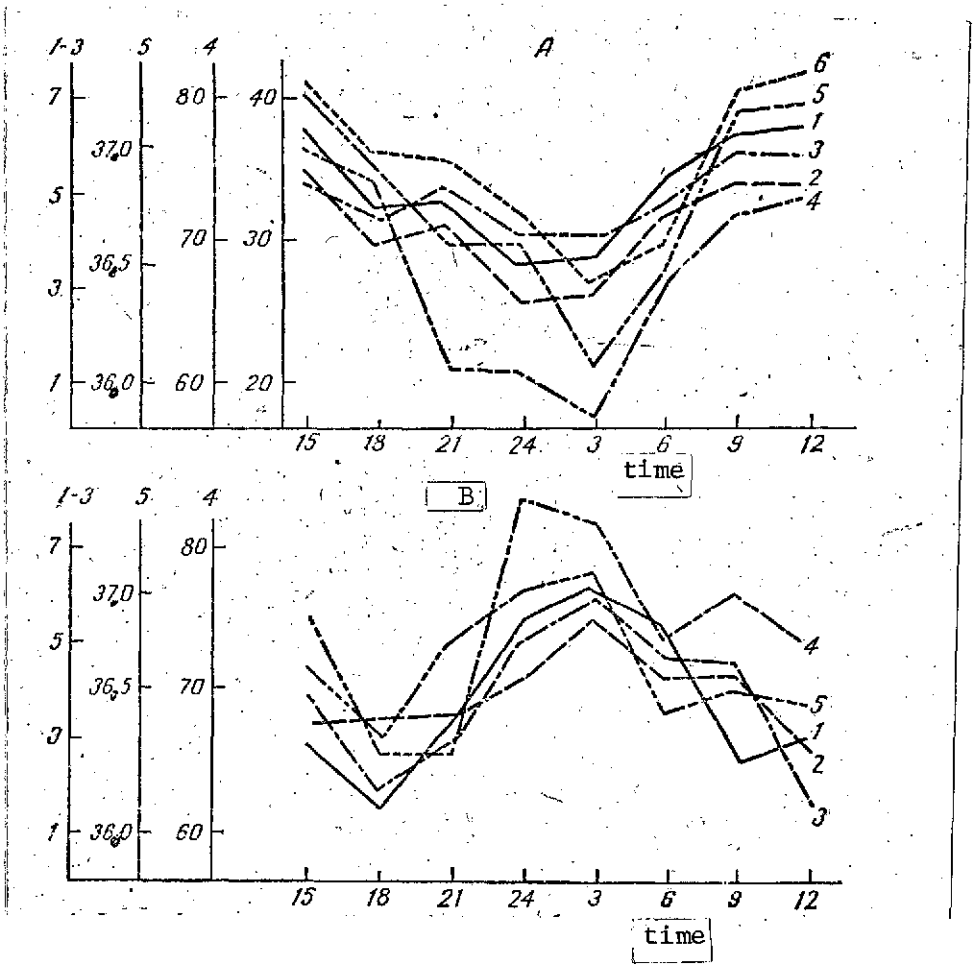

Figure 2. Circadian rhythm of psychophysiological functions

A — student I with morning type performance; B — student P with morning type performance. 1 — feeling; 2 — activity; 3 — mood; 4 — pulse rate; 5 — body temperature; 6 — strength of right fist.

For mathematical proof of conformity between test results by the Hampp method and the physiological study, the latter results were converted to numer-

ical values which could be compared for the three groups divided according to Hampp's method. For this we used a coefficient analogous to the coefficient of circadance suggested by R. M. Bayevskiy and T. D. Semenova which is the ratio between indices of physiological functions in daytime hours (first half of the day) and indices measured in the evening hours (second half of the day). This coefficient, which we called the coefficient of functional optimum, makes it possible to integrate the results of functional tests of students during the period of wakefulness.

The coefficient of functional optimum fluctuated from 0.7 to 1.5; the amplitude of fluctuations differed according to various indices. Thus, for temperature the coefficient of functional optimum varied from 0.9 to 1.01, for feeling from 0.72 to 1.5, for activity from 0.72 to 1.4, for mood from 0.7 to 1.5, etc. Evidently it is only possible to evaluate the functional state of the body during wakefulness by this index very conditionally. As such a conditional value we selected a coefficient of 1.0. Based on the assumption that a coefficient of less than 1.0 will characterize a high level of functions in the second half of the day, it was considered typical of persons with the evening type of performance, while a coefficient over 1.0 was expected in persons with the morning type. As an illustration, Fig. 3 gives coefficients of functional optimum for a student with the morning type and a student with the evening type of performance efficiency. /144

The correlation coefficient between the coefficient of functional optimum obtained by studying body temperature during the period of wakefulness and the distribution of subjects by type of performance was 0.66 ($P<0.01$). This suggests that the use of such a test to identify rhythms will be very fruitful.

In all subjects, a correspondence was observed between the optimum performance and optimum physiological functions.

Thus, periods of maximum performance to a significant degree are determined by the circadian rhythm of physiological functions.

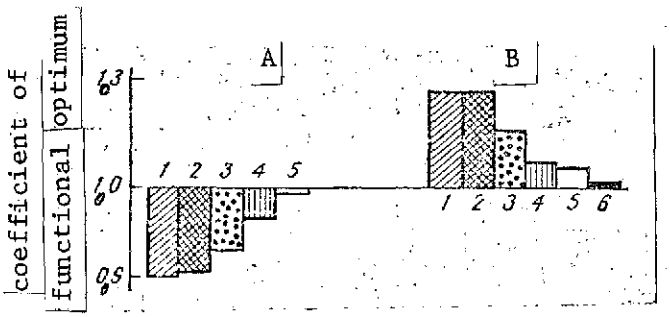

Figure 3. Coefficients of functional optimum

A — student with evening type of performance efficiency; B — student with morning type; 1 — feeling; 2 — activity; 3 — mood; 4 — body temperature; 5 — pulse rate; 6 — strength of right fist.

Increased performance at certain hours of the day indicating predominance of ergotropism in comparison with a predominance of trophotropism in the period of rest and relaxation is without doubt an expedient phenomenon of circadian organization. Periods of both high and low vital tone are biologically predetermined and depending on their time distribution reveal various biorhythmological types.

Sleep and wakefulness are basic conditions of the body and normal interaction between them creates the necessary prerequisites for full-value creative work (A. M. Veyn). Therefore, the biological rhythm of performance efficiency must be taken into consideration in evaluating the functional state of the body as well as in organizing professional work and orientation.

CONCLUSIONS

1. Periods of high performance are determined by the circadian rhythm of physiological functions. The subjective performance optimum, as a rule,

coincides with a high level of physiological functions.

2. The use of biorhythmological characteristics of the human body will make it possible to approach a sufficiently promising solution to the problem of organizing occupations.

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